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Electric Power for China's Modernization: The Hydroelectric Option

A Research Paper

ER 80-10089U
May 1980

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Electric Power for China's Modernization: The Hydroelectric Option

Key Judgments

Shortages of electric power probably will restrain the development of China's economy throughout the 1980s. Such shortages have been a major factor in the recent slowdown of economic growth and probably will prolong the current period of economic readjustment.

To help meet future power needs, the Chinese are seriously considering a massive program to construct hydroelectric power stations. China has the world's largest hydroelectric resources. Although the bulk of these resources is located in remote areas of west and southwest China, an estimated 145,000 to 220,000 MW of exploitable hydroelectric capacity can be transmitted to major industrial centers using China's existing technology. This is about three to five times China's total installed capacity (thermal and hydro) at yearend 1978.

The proposed new hydro projects are much larger than any previously built in the People's Republic of China (PRC) and will undoubtedly require extensive foreign assistance. The Chinese lack the technical, managerial, and financial resources to build the huge hydroelectric projects that are required to permit the economy to expand at an acceptable rate during the 1980s. Work on massive amounts of new hydro capacity will have to start in 1980 and 1981 to bring on line in the late 1980s enough hydroelectric plants to maintain hydro's present share of generation. Chances are good that the PRC will sign major contracts within a year or two to obtain foreign help in building several of the projects currently under consideration.

The Chinese will probably push construction of new thermal plants to help meet demand until the new hydro projects come on line. The PRC is pushing a short-term electric power policy to narrow the gap between supply and demand during the current period of readjustment. This program calls for accelerated work on thermal and hydroplants currently under construction, increased utilization of existing plants, and nationwide conservation.

The success of China's hydroelectric program depends on a number of factors. Political stability over the next five- to 10-year period is essential; a return to the internal instability and confused economic planning of the past would be disastrous. An adequate source of financing also is crucial to the success of the program. The electric power industry, moreover, will have to be given priority over most other industrial sectors for domestic capital and for access to long-term foreign loans.

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Introduction

China has embarked on a new program to exploit its enormous hydroelectric resources. The present government recognizes the need to improve the power system and has put hydroelectric plants high on its list of investment priorities. It has begun taking measures to implement the hydroelectric development program including investigations of what foreign countries can provide in terms of technical help, equipment, construction contracts, and financial aid.

This paper discusses the choices Beijing faces in its attempt to overcome the problems of providing energy for modernization and the role that hydroelectric power might play in the modernization program. Official information on China's plans is meager; we believe the Chinese have not yet worked out all of their priorities. Nevertheless, we have been able to piece together the general thrust of their hydroelectric construction program.

China's Energy Supply

China is well endowed with fossil fuel and hydropower resources. Coal reserves of at least 1.5 trillion metric tons are exceeded only by those of the United States and the Soviet Union, ultimately recoverable oil and natural gas reserves [1] may amount to about 100 billion barrels of oil and oil equivalents, and China leads the world in hydropower resources.

These energy resources, except for oil, have hardly been tapped. Despite a rapid growth in oil production, in 1978 coal still provided 73 percent of China's energy; oil was the source of about 23 percent; natural gas and hydroelectric provided 3 and 1 percent, respectively (see table 1).

[1] Ultimately recoverable reserves refers to that part of the oil *in situ* that could eventually be located and produced given reasonable assumptions about technology and development costs.

Table 1

China: Energy Supply, 1978

	Units	MTCE [1]	Percent
Total	**625.2 MTCE**	**625.1**	**100.0**
Coal	616.0 MMT [2]	458.4	73.3
Oil	94.7 MMT	142.0	22.7
Natural gas [3]	13.7 billion cubic meters	18.1	2.9
Hydroelectric	53.0 billion kWh	6.6	1.1

[1] Million metric tons of standard coal equivalent (7,000 kilocalories per kilogram).
[2] Million metric tons. Data are for raw coal.
[3] See table B-1 for a recently revised natural gas series.

More importantly, energy production has not kept up with demand. This reflects both inadequate planning and poor implementation of economic plans. The Chinese must coordinate energy production with other parts of their economic development program and target an appropriate mix of fuels and electric power.

Energy Production Problems

China's energy industries suffer from a variety of problems that Beijing must address as it readjusts energy investment priorities. Shortages of all forms of energy are common, and huge investments in new production capacity are needed if economic growth is to be maintained.

The rate of growth of oil output, for example, has declined in the last few years because production at large first-generation fields has reached a plateau and high-volume production at the next generation has been delayed by China's limited ability to handle some technical aspects of exploration and development. While the effects of slower growth of production can be

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mitigated for several years by substituting coal for oil in power plants and by changing the refining mix, new fields must be developed for future consumption and export.

Increases in China's coal production during the past two decades were achieved mainly by expanding existing mineshafts and opening small rural mines. This growth formula will no longer work; large-scale investment in new, large, modern mines is required.

Future Energy Needs

Until a new economic development plan is announced, the rate of growth of China's energy needs is left to conjecture. We estimate that the 1970-1978 energy/GNP elasticity—that is, the ratio of the rate of growth of energy supply to the rate of economic growth—was 1.4. Chinese officials admit, however, that their industries waste a lot of fuel, and energy conservation efforts, which are part of the economic readjustment program, were fairly successful during 1979. But these initial achievements for the most part represent one-time gains and it remains to be seen what medium- to long-term effect, if any, conservation programs will have on China's energy/GNP elasticity.

Several facets of China's present development policies run counter to its conservation program. The Chinese, for example, plan to increase investment in industries that consume large amounts of energy, such as nonferrous metals and transportation. Agriculture, no doubt, will also become more energy intensive if trends in mechanization and use of chemical fertilizer continue. In addition, demand for electric power in the residential sector could take off if more televisions and household appliances are put on sale in China.

Additional demand will be placed on energy growth by China's desire to export oil and coal. China should be able to meet its oil and coal export commitments to Japan and a few other countries for the early 1980s if new fields and mines come into production on schedule. Any significant expansion of exports, however, would require considerable luck in locating large deposits of oil and large investments in development of oilfields and coal mines as well as the infrastructure to serve them.

Table 2

China: Electricity Production

Year	Total Electricity (Million kWh)	Per Capita (kWh)
1949	4,300	8
1952	7,300	13
1957	19,300	30
1965	63,000	84
1970	107,000	126
1975	187,000	196
1976	203,460	210
1977	223,400	226
1978	256,550	256

The substitution of nonexportable hydroelectricity for fossil fuels or thermally generated electricity could reduce the rate of growth of demand for oil and coal over the long run in China. Therefore, hydropower resources offer an attractive and renewable energy source for badly needed power generation in many parts of the country.

China's Electric Power System

After 30 years of Communist rule, China's electric power system is still in the early stages of growth. Generation and transmission technology is about 10 to 20 years behind the West. Regional grids are not well developed and local grids tend to be small with few ties with their neighbors. Nevertheless, from 1949 to 1978 generation increased from 4.3 billion kilowatthours (kWh) to 256.6 billion kWh, and annual generation per capita grew from 8 to 256 kWh (see table 2).

Although China has about 90,000 power plants, most are small; a few hundred large power stations (capacities greater than 24 megawatts) generate most of the power. Nearly 75 percent of the generating capacity in large plants is thermal, mostly coal-fired. The balance is hydro (see table 3). Thermal generation predominates in north, northeastern, and central China; hydropower in the south, southwest, and northwest.

Table 3 — Megawatts

China: Generating Capacity in Large Power Plants [1]

	1975	1976	1977	1978	1979 [2]
Total	**35,600**	**37,700**	**41,600**	**45,600**	**47,600**
Hydro	11,300	11,600	12,100	12,700	12,800
Thermal	24,300	26,100	29,500	32,900	34,800

[1] Plants with capacities greater than 24 megawatts.
[2] Data are for mid-1979. Data for other years show capacity on 31 December.

Power Shortages

China's electric power system has not grown fast enough to meet the increasing demand from industry and agriculture. There have been widespread reports of factories operating at 70 to 80 percent of capacity because of electricity shortages, and many new plants have been unable to start operations because of insufficient electric power.

In addition, inadequate transmission lines are frequently overloaded, which multiplies losses and undermines system stability. Blackouts, brownouts, and fluctuations in frequency are nationwide problems. Moreover, the problems inherent in an inadequate power system have been compounded in recent years by drought, which reduced hydroelectric generation in many parts of the country and increased the need for electricity to operate irrigation pumps, and localized coal shortages which undermined thermal generation in some areas.

In order to maximize generation, the Chinese keep little generating capacity in reserve. As a result, major electricity users on the same grid often coordinate their hours of operation in order to maintain a high load factor. When demand exceeds supply, load is reduced by cutting off low priority consumers. Residential consumers, whose use is generally limited to a few kilowatthours per month, have the lowest priority. Average residential use in China is estimated to be 10 kWh per month per household which surpasses India's but is minute when compared to about 900 kWh per month in the United States.

Future Demand for Electricity

In their recent drive to conserve electricity, the Chinese have claimed that 10 billion kWh of electricity can be saved annually if line losses in rural areas—reportedly as high as 20 percent of generation—are reduced and if major industrial enterprises cut per unit consumption to its previous minimum levels. While some line losses can be eliminated by improving transformer and circuit breaker maintenance, other savings require investments to expand transmission capacity. If such investments are approved, several years would be required to install additional transmission lines.

China's leaders are moving the economy along paths that promise to continue past trends in growth of electricity consumption. We estimate that China can reduce growth of electricity consumption by only a few percentage points at most within the next five years without a decline in the growth rate of GNP. This would slow the upward trend in the ratio of electricity generation to GNP only slightly.

Through mechanization and the use of chemical fertilizer, Chinese agriculture requires increasing amounts of energy. Intensive cultivation requires not only tractors and combines but pumps for irrigation and drainage. Although many of these pumps are run by internal combustion engines, electricity has become the preferred power source in recent years. This policy is likely to continue in order to free up petroleum products for transportation use or for export.

China's heavy industry sector will become more electricity intensive as the quality of metals produced is upgraded. Planned increases in the output of high-quality steel and steel alloys will require increased use of electric furnaces. Expansion of rolled steel products also will increase the intensity of electrification of the steel industry. Beijing also plans new investments in nonferrous metals, particularly aluminum and copper, production of which requires huge amounts of electricity.

Expansion of the light industry sector also will require more electricity to provide lighting, motive power, and perhaps some processing heat. Although light industries are not as energy intensive as heavy industries, the factories will require the construction of many new power plants. New products from light industrial plants, such as televisions and household appliances, will spur electricity demand in the residential sector.

Adjusting Electricity Supplies

Power shortages probably were a major impetus for the period of economic readjustment. The Chinese realize that investments in power plants must be stepped up relative to investments in other heavy industry and have announced their intention to do so. Large power plants, however, require four or more years to build. Beijing therefore has adopted a short-term strategy to ameliorate the problem while officials draw up electric power development plans for the mid- and late 1980s.

During the period 1979-81 Beijing is emphasizing increased efficiency in electricity generation, transmission, and use. Efforts are being made to boost thermal power plant output by increasing the utilization of turbogenerators through improved maintenance. *People's Daily* reported that such efforts restored 2,400 megawatts (MW) of idle capacity to service in 1978, facilitating the generation of an extra 40 million kWh daily in 1979. Beijing also has adopted the goal of reducing electricity consumption within power plants and of lowering transmission losses from the present 16 to 17 percent of gross generation to below 15 percent. In Europe, by contrast, plant use and line losses totaled 11.8 percent of output in 1976. Consumers of electricity also are expected to avoid inefficient and low priority uses.

China is speeding up power plant construction as well. New additions to capacity during the adjustment period will come from plants that already are well under way. Beijing announced that work was being accelerated on a number of thermal power plants as well as the Baishan, Dahua (Guangxi), Longyangxia, Wujiangdu, and Xierhe hydroelectric projects, some of which may start generating by 1980.

Because of the long leadtimes involved, the push on power plant construction will not have a great impact within three years, the original length of the readjustment period. In fact, it remains to be seen if China can do much more by 1982 than prevent the shortages from getting worse. Beijing apparently realized this and released modest electric power goals for 1979: to increase generation by 7.2 percent above 1978 and to boost generating capacity by 2 percent. In comparison, growth in these respective areas averaged 11.1 percent and 9.6 percent annually from 1975 through 1978. To better allocate electricity supplies according to national priorities, China is centralizing control of electricity distribution.

Generating Options

Nuclear, conventional thermal, and hydropower plants constitute China's options for new baseload generation to come on line throughout the 1980s.

It appeared that China had rejected nuclear power in the spring of 1979 when it suspended a deal with France for two 900-MW pressurized-water reactors valued at about $2 billion. This deal was the culmination of a 1978 review of generating options and an in-depth look at Western-made nuclear equipment. Some Chinese leaders, however, renewed the call for nuclear power during the winter of 1980. We expect that if a Chinese nuclear power program is implemented, it will be small initially, not exceeding a very minor fraction of installed capacity before the end of the decade.

Most, if not all, new thermal capacity will be coal-fired. China is shifting away from the use of oil for power production and has been converting to coal power plants that have boilers designed to use either fuel. Natural gas supplies are still tight and natural gas probably will not be a significant power plant fuel through the 1980s.

At present, China appears to be leaning toward a mix of hydroelectric and coal-fired plants that will balance the local availability of water power and coal with a construction pace in tempo with its overall modernization effort. Because of the leadtimes for very large hydro stations, coal-fired thermal plants will continue to be the major source of new generation before 1987 beyond those power plants now under construction. We estimate that in China an average of seven years will be required from the day work starts until the first unit is brought on line at a hydroelectric station with a design capacity of 250 MW or more. Additional units could be added at a much quicker pace. In the past, however, Chinese hydroelectric construction was greatly slowed by economic and political instability and it took an average of 14 years from ground breaking to completion of hydroelectric plants of this size.

When speed of construction is not a constraint, hydroplants offer the Chinese many advantages. Hydro stations consume no coal or oil—exports of which the Chinese would like to increase. The environmental impact of hydroplants, unlike those of thermal plants, can be turned into benefits via multipurpose development that combines irrigation, flood control, improved navigation, or commercial fishery development with power generation.

The main shortcomings of hydro to the Chinese will be the large inputs of materials needed for dam construction and transmission equipment, and the possible need to flood good farmland for reservoirs. On the other hand, thermal power may be constrained by difficulties in transporting coal to power plants.

Electricity Supply and Demand Prospects for Mid- and Late 1980s

Because of long leadtimes China must step up its power plant construction activities during the early 1980s if power supply is to keep pace with the demands of the economic modernization drive, which will be particularly strong by the late 1980s. In addition to those plants presently under construction, China will have to add thermal power stations and perhaps small hydros to cover short-term needs. They also have to begin construction of proposed large hydroelectric plants no later than 1982.

To estimate China's need for additional generating capacity to 1990, we compared electricity demand and power station construction scenarios. For most industrializing countries, including China, the ratio of electricity supply to GNP increases over time. Demand was estimated by applying the projected trend of the 1970s in the electricity supply/GNP ratio [2] to GNP projections. Because China's modernization program is emphasizing industries and activities that are electricity intensive, we believe that despite conservation programs, the electricity/GNP ratio will continue to grow at least at historic rates over the mid- to long term.

The growth of electricity demand through the 1980s will be directly related to the rate and areas of expansion of China's economy. We feel that a 7-percent rate of GNP growth is consistent with the industrial and agricultural targets announced under the suspended 10-year plan (1976-1985) and represents the probable upper limit. During the period of economic readjustment, which is likely to require three or four more years, growth will be slower, perhaps on the order of 5 percent. GNP growth, however, cannot be sustained even at this rate unless China accelerates new power plant construction. At the lower end, electricity available from existing power plants and those now under construction can sustain only a 3-percent rate of GNP growth, through the mid-1980s—a rate of growth the Chinese would find unsatisfactory.

Based on 3-, 5-, and 7-percent GNP growth rates, electricity generation will have to increase 50 to 100 percent over the 1978 level by 1985 (see table 4). Between 76,000 and 104,000 MW of capacity will be needed for these levels of output. By 1990 electricity output will have increased by 100 percent over 1978 production if the economy grows by 3 percent; 150 percent if the economic growth rate is 5 percent; and 215 percent if the economic growth rate is 7 percent.[3] Capacity requirements for 1990 will be about 101,000, 130,000, and 165,000 MW, respectively (see chart, page 7).

Meeting 1985 and 1990 Capacity Requirements. Future capacity will come from three sources: power plants now operating, those under construction, and those not yet under construction.

During 1978 China averaged about 50,500 MW of generating capacity, including about 5,000 MW in small hydroelectric plants. By 1985, however, an estimated 2,400 MW of present thermal capacity will have exceeded its useful life for baseload generation. By 1990, an estimated 7,800 MW of thermal units will

[2] Data from the 1960s were not used because they were incomplete and because the Cultural Revolution years were considered atypical. China does not have a measure of national output that is equivalent to GNP. NFAC estimates of GNP were used.

[3] Electricity is a necessary but not sufficient requirement for economic growth. Power shortages can constrain China's growth, but the elimination of shortages will not necessarily result in rapid economic expansion.

Table 4

China: Meeting 1985 and 1990 Electricity Requirements Corresponding to Selected Rates of GNP Growth

	3-Percent GNP Growth	5-Percent GNP Growth	7-Percent GNP Growth
1985			
Electricity required in 1985 (billion kWh)	388	445	507
Output available from plants operating or under construction in 1979 (billion kWh) [1]	380 to 411	380 to 411	380 to 411
Additional needs in 1985 (billion kWh) [2]	0 to 8	34 to 65	96 to 127
Additional capacity required, 1980-85 (MW) [3]	0 to 1,300	5,700 to 10,800	16,000 to 21,200
1990			
Electricity required in 1990 (billion kWh)	512	644	809
Output available from plants operating or under construction in 1979 (billion kWh) [1]	362 to 407	362 to 407	362 to 407
Additional needs in 1990 (billion kWh) [2]	105 to 150	237 to 282	402 to 447
Additional capacity required, 1980-90 (MW) [4]	20,000 to 28,000	44,000 to 53,000	75,000 to 84,000

[1] The higher figure for each year is based on the assumption that all power plants under construction in 1979 are completed at a fast but achievable rate, that capacity under construction is 10 percent higher than in the lower case, that hydroelectric plants have a utilization rate of about 50 percent, that thermal plants have a utilization rate of 68 percent, and that thermal units over 30 years old and small hydros have a utilization rate of 25 percent.
The lower figure is based on the assumption that additions to capacity lag behind the optimal rate by 10 percent; that hydroelectric plants have a utilization rate of 46 percent; thermal plants, 68 percent; and small hydros, 23 percent. In addition we assume that thermal units more than 30 years old are retired.
In both cases we assume that small hydro capacity levels off at 13,550 MW by 1985. After that date we believe that a growing high-voltage transmission system will be the major source of new electricity supplies for rural China. New small hydro units will be added at a rate about equal to the rate of retirements of old small hydros.

[2] Electricity that will have to be generated at plants not yet under construction in 1979.

[3] Computed by assuming that nearly all capacity supplying additional needs in 1985 will be thermal units with a 68-percent utilization rate.

[4] Computed by assuming that one-third of capacity added during 1980-90 but not under construction in 1979 is hydroelectric, with a utilization rate of 46 percent, and the balance is thermal with a utilization rate of 68 percent. These estimates take into account the assumption made in footnote 3, above.

be in this category. Old thermal turbogenerator units are generally either scrapped or reserved for peak load or emergency use. During the late 1980s, increasing amounts of new capacity will go to replacing wornout units.

By late 1979 more than 55 large power plants totaling 18,000 MW of capacity were under construction. At the same time an estimated 8,000 MW were being added to operating power plants and about 3,500 MW of small hydro units were under construction. By 1985, at least 25,000 MW of this should come on line.

Completion of units now under construction plus plants in operation in 1979 would be barely adequate to meet 1985 needs if the Chinese economy expands at only a 3-percent growth rate, if power plants are completed at an optimal rate, and if above average rainfall boosts hydroelectric output. If none of these conditions obtain, additional generating capacity will be needed, up to a possible 21,200 MW which corresponds to a 7-percent GNP growth rate. By 1990, power plants not yet under construction will have to provide between 20,000 and 84,000 MW of capacity.

Hydroelectric plants of 250 MW or larger that are not yet on the drawing boards probably could not come into service until at least 1987. Therefore, the bulk of capacity coming on line through 1985 and not under construction in 1979 will be thermal.

China can build both thermal and large hydroplants to meet capacity requirements for the late 1980s. By 1987 China's desire to harness very large hydropower sites now being considered can start to bear fruit. But major economic planning decisions and commitments to foreign contractors must be made soon.

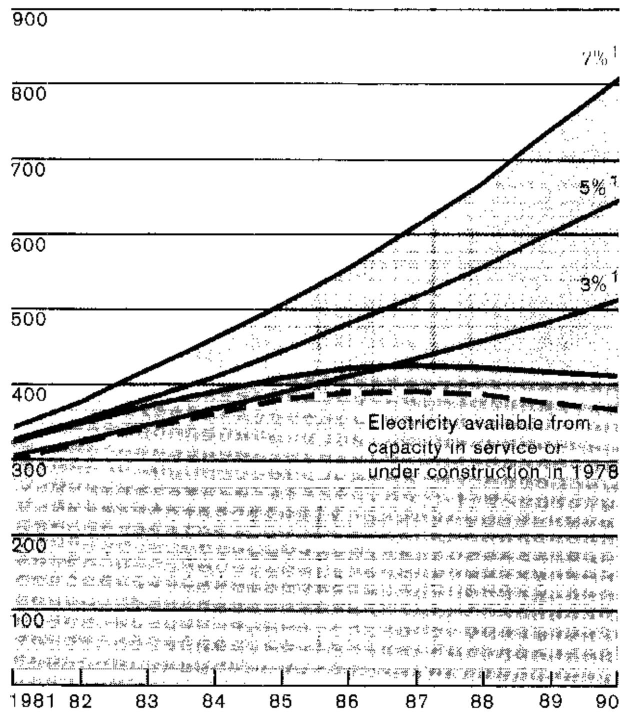
In order to cover part of the electricity needs projected for the late 1980s with hydropower, a substantial amount of new construction must start shortly. For example, for the 5-percent rate of GNP growth scenario, if one-third of the capacity added after 1986 is to be hydro, work would have to start on about 12,000 MW [4] of additional hydro capacity during 1980. If two-thirds of 1987-90 capacity additions are to be hydro, work on about 26,400 MW of hydro capacity should be initiated in 1980.

Because of the limitations of China's hydroelectric construction industry and shortages of foreign exchange, Beijing is unlikely to commit itself in 1980 to building more than 12,000 MW of capacity in very large hydroelectric plants, and even this figure may be high. Nevertheless, the figure is useful for illustrating the increases in power plant construction that would correspond to a 5-percent rate of economic growth. To expand its economy at this rate to 1990, China should have 20,000 to 25,000 MW of new power plants, both hydro and thermal, under construction by the end of 1982. This is an 11- to 39-percent increase over large plants under construction in 1979.

The prospect of undertaking such a potentially huge program of power system expansion or of suffering the costs of faltering economic growth in the mid- or late 1980s if power plant construction proceeds at a slower pace poses a difficult problem for Chinese planners. We would not be surprised if power supply difficulties influenced the extension of the present readjustment period beyond its originally slated three years. By allowing more time for readjustment, Chinese planners may be able to slow the growth of electricity demand. This would not only give them a better opportunity to sort out their development priorities and develop long-range economic plans, but would also allow them to base electricity generation on renewable water power resources, rather than on coal, an exhaustable and exportable commodity.

[4] Assuming new plants have an average size of 2,400 MW, which is the range of plants the Chinese have been considering.

China: Additional Electricity Required



1. Electricity generation required for stated GNP growth.

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Hydropower in China

China's ability to mobilize its hydroelectric industry to meet electricity needs for the 1980s and 1990s will be constrained by more than construction leadtimes. The capabilities of its hydroelectric construction industry, the quality of power system planning, its openness to Western technology and availability of hard currencies are central to an analysis of China's ability to increase its dependence on hydroelectric energy.

Hydroelectric Resources

The size and location of resources have been persuasive factors in Beijing's decision to increase the emphasis on hydropower. The first thorough postliberation survey of China's rivers—completed in 1955—placed the

Table 5

China: Geographical Distribution of Hydroelectric Resources, 1979

Region	Mean Theoretical Hydro Potential (MW)
Total	**571,000** [1]
North East (Liaoning, Jilin, Heilungjiang)	15,800
North (Hebei, Shanxi, Nei Monggol, Beijing, Tianjin)	11,300
North West (Shaanxi, Gansu, Qinghai, Sinkiang, Ningxia)	52,400
South West (Sichuan, Guizhou, Yunnan)	269,900
Xizang	148,100
South Central (Henan, Hubei, Hunan, Guangxi, Guangdong)	56,500
Eastern China (Jiangxi, Shandong, Jiangsu, Anhui, Zhejiang, Fujian, Shanghai)	16,900

[1] Chinese officials rate total mean theoretical hydro potential at 580,000 MW. But this includes about 9,000 MW for Taiwan.

mean theoretical hydroelectric potential of mainland China at 536,000 MW.[5] As a result of subsequent surveys, the Ministry of Water Conservancy and Power (MWC&P) raised this estimate to 571,000 MW [6] (see table 5).

With 330- kilovolt (kV) transmission capability—the highest voltage now used in China—some 290,000 MW of hydro potential lie within reach of cities with populations exceeding one million. Of this an estimated 145,000 to 220,000 MW are now economically exploitable. These figures will grow as 500-kV lines come into use. So far China has developed only 13,000 MW of hydro capacity in large plants and an estimated additional 11,000 MW of large hydroelectric plants are under construction.

[5] The most commonly sited figure for hydro potential, 545,000 MW, includes Taiwan.
[6] If Taiwan is included, 580,000 MW.

Current political and technological conditions preclude the development of the remaining half of China's hydropower potential. Rivers comprising the border with the Soviet Union are unlikely to be developed unless relations between the two countries are patched up. Part of the output of any new power plants on the Yalu or Tumen Rivers would go to North Korea. In addition, many hydrosites—including one with the highest potential in the world—lie well beyond the range of current Chinese transmission technology to deliver power economically to major population centers.

Hydroelectric Development, 1949-79

From 1949 to 1959 the Chinese made great strides in their ability to develop hydropower resources and embarked on an ambitious construction program. Immediately following the revolution, the Chinese surveyed their large rivers for energy potential. Under the first five-year plan (1953-57) Beijing sketched—with Soviet help—plans for the multipurpose development of a number of rivers including the Huang He (Yellow River), the Chang Jiang (Yangsi), and the Xi Jiang (Pearl). A detailed plan for 46 high dams on the Huang He had been fleshed out by 1954. With Soviet, Czechoslovak, and East German aid China started 26 hydroelectric stations; 11 with a total capacity of 530 MW—more than twice China's 1949 hydro capacity—were completed by yearend 1957.

Hydroelectric construction was greatly expanded under the second five-year plan which began with the Great Leap Forward. An ambitious hydropower program called for work to begin on 275 projects with design capacities totaling 25,000 MW, including nearly all of China's present hydroplants larger than 500 MW.

The excessive efforts of the Great Leap Forward crippled China's economy, slowing construction. The Soviets dealt the hydro program another blow by withdrawing their aid in 1960. Most planned hydroelectric stations never got off the drawing boards and many that did, especially the larger ones, were not completed for more than 10 years.

Just as economic collapse and international politics took their toll on hydroelectric construction in the early 1960s, in the late 1960s and early 1970s the program fell prey to internal politics. The Cultural Revolution and factional political struggles destroyed much of the hydro program's foundation that had been laid during the 1950s. During the late 1960s and early 1970s hydro surveying, design, and research organizations were dismantled and many technical personnel were sent to the countryside as agricultural laborers.

By the late 1970s, however, China's hydroelectric construction industry was again being strengthened. Eleven hydro projects, each exceeding 250 MW capacity, are now under construction (see table A-1). These are providing Chinese engineers and geologists with opportunities to develop or sharpen many of the skills they will need to undertake much larger projects.

Mixed Results

Despite the unstable economic and political conditions of the past, the Chinese have demonstrated that they can design and build hydroelectric equipment and plants in a variety of sizes and that under the right circumstances they can complete plants of a few hundred megawatts capacity in five years. China now has about 100 large hydroelectric plants, more than 35 of which exceed 99 MW capacity (see table A-2 and foldout). Nearly all the hydroplants have been built since the revolution. Although the plants are not based on sophisticated engineering, the tallest dam—147 meters—and the largest turbogenerator unit—rated at 300 MW—are significant achievements. On the other hand, the Chinese are at least 10 to 20 years behind the United States in high dam construction, turbogenerator design, and electricity transmission technology.

The Sanmen Fiasco. As a consequence of inadequate planning, the Chinese have run into some serious problems at individual hydroelectric sites. The most outstanding was the failure of the Sanmen project on the Yellow River. This Soviet-assisted project originally had a designed capacity of 1,100 MW. After the dam was completed in 1960, the rapid silting of the reservoir created a potential flood hazard in the Guanzhuang Plain and at Xian. China blamed the Soviets for failing to assess the rate of sedimentation accurately. The Soviets charged that the Chinese ignored the part of the plan calling for construction of 20 dams that would have trapped silt on the Yellow River's tributaries upstream from Sanmen. Since 1960, the Chinese have modified the dam to sluice the silt through, which also forced a reduction in designed generating capacity to 250 MW.

The Chinese also have had difficulties with the giant Gezhouba project located in Hubei. Unexpected problems, including silting, forced a two-year work suspension while the Chinese redesigned parts of the project.

Small Hydroelectric Stations

One area in which China has made great strides is in tapping hydropower resources at sites with little potential, making China unique in the use of small hydrostations. As of April 1979, 88,000 of these plants provided rural areas with a total of 5,380 MW of generating capacity. The average size was only 61 kW and their aggregate output was only 10 billion kWh yielding a utilization factor of about 20 percent. This means that on the average the small hydros were running at less than half the rate of other hydroelectric power plants in China.

Small hydroplants contribute significantly to rural China's development. They power pumps for irrigation and drainage and provide electricity to rural households. In addition, they enable rural areas to run small factories to manufacture chemical fertilizers, cement, and agricultural machinery. Small hydro stations, however, are not a panacea to rural electricity requirements. During droughts, when electricity is most needed for running irrigation pumps, power output often must be curtailed because of reductions in the volume of water in small streams.

Beijing and provincial governments are actively supporting the small hydro program in order to increase rural productivity. Chinese officials have called for small hydro additions of 1,000 to 1,200 MW per year for 1979-81; about 1,500 MW per year for the 1980s; and 2,000 MW per year in the 1990s. These plants, therefore, will continue to be a significant source of electricity for rural China at least until a nationwide transmission system is developed.

Hydropower Development Plans

The Planning of Power System Expansion

In reviewing power plant construction options, Beijing's planners must consider the availability of raw materials, skilled labor, generating equipment, and foreign exchange—availabilities that are affected by competition among ministries as well as by technical constraints. Careful attention also must be given to long-term economic planning of regions around power plant sites and the way in which regional development meshes with provincial and national development goals.

We know little about the political process from which electric power construction results in China's centrally planned economy. In any event, the relative political strength of the Ministry of Power Industry vis-a-vis other agencies competing for capital and foreign exchange probably will be an important factor in the allocation of resources to power development.

On the other hand, the fact that almost all of the ministries need ample supplies of electricity to carry out their functions may make approval of power plant construction easy to obtain. For multipurpose water resource projects, in particular, many ministries, such as Water Conservancy, Power Industry, Machine Building, Communications, and Agriculture would be involved. The involvement of so many ministries in multipurpose projects, however, may make project coordination difficult and provide greater opportunity for conflict and misunderstanding.

The expansion of the electric power system, particularly the development of hydroelectric resources, makes good economic sense and should be politically acceptable. There are good reasons to believe that when the veil of the economic readjustment period is lifted on a new development plan, hydroelectric construction will play a major role. We believe, however, that construction of large new projects will not be completed until the late 1980s and early 1990s—much later than the Chinese presently expect.

Visions and Revisions: Readjusting Hydroelectric Development Plans

China's hydroelectric construction program should be strengthened by two recent measures: (a) the suspension of the 10-year plan (1976-85) and the establishment of a period of readjustment (1979 to the early 1980s) and (b) a reordering of priorities that will increase the proportion of investment going to the power industry even though investment in most other heavy industries will be cut. These measures will reduce growth in demand for electric power both in the short term and the long term; thus, besides freeing up funds for hydroelectric construction, they will allow more leadtime for completion of hydroelectric projects.

The Suspended 10-Year Plan. A vague electric power policy, a sketchy 10-year plan, unofficial generating capacity goals for 1985 and 2000, and a list of proposed projects had been loosely guiding power system development for 1976 to 1978. The electric power development policy called for the following measures:

- Both thermal and hydropower plants are to be built. The choice is to depend on the availability of coal or hydropower resources. Some thermal plants are to be constructed in hydropower-rich areas to provide backup in times of drought.
- Large, medium, and small plants are to be constructed.
- Large power plants, especially hydro stations, are to form what the Chinese call the "backbone" of the emerging power system.
- Small stations, especially those powered by water, are to be built for rural electrification.

Until July 1979, directives for implementing this policy were outlined in the now suspended 10-year plan. It called for work on 20 hydro stations of at least 1,000 MW each—plus 10 very large thermal plants—to be under way or completed by 1985. Many of the hydro stations had been originally scheduled for development during the 1950s (see table A-3).

During the fall of 1978 and winter of 1979 Beijing seemed to be emphasizing very large multipurpose projects on the Chang Jiang and the Huang He. The mammoth 25,000 MW Sanxia project led the list. Beijing discussed it seriously with the United States and Japan and led Japan to believe that the Longmen (1,500 MW), Xiangjiaba (4,000 to 6,000 MW), and Daliushu (1,500 MW) projects also had high priority.

Sanxia would have tied up large amounts of capital—Japanese and Chinese estimates of its cost range from

$7.8 to $12.5 billion to which transmission facilities would add billions more. The project would require eight to 10 years of construction, according to Chinese estimates, before the first stage was operating and would take 20 years to complete. Sanxia would absorb tremendous amounts of resources, would have no payoff for a decade, and would concentrate an inordinate amount of generating capacity in one area to the detriment of power system growth in the rest of China. Nevertheless, there are some indications that the Ministry of Water Conservancy would like to keep the option of its construction open, probably for possible long-term benefits from diverting water from the Chang Jiang to the North China Plain.

Shifts in Priorities. In late 1979, the Chinese shifted some priorities, though it is not clear that this shift is permanent. Indeed, an official of the Ministry of Power Industry told the US Economic Counselor in Beijing that the electric power plan during the readjustment period had not yet been decided. Vice Premier Gu Mu told the Japanese that plans to build Xiangjiaba, Longmen, and Daliushu have been shelved. Chinese officials are still debating the Sanxia project. Instead, projects like Longtan [7] (3,000 MW) and Jinping (3,600 to 4,500 MW) are receiving increasing attention. These two projects are designed to provide power to existing or proposed nearby metallurgical facilities. Longtan will power a new aluminum plant; Jinping will supply electricity to the steel plants near the Sichuan-Yunnan border.

The review of the hydro development plan is likely to be a lengthy process, because the debate is focusing around issues that bring the Ministry of Power Industry into competition with other ministries for resources. Among the questions that need to be resolved are: (a) the choice between domestic and foreign technology, (b) the disposition of limited amounts of foreign exchange, and (c) the extent of transmission line development.

Domestic or Foreign Technology. If China is going to proceed rapidly with hydroelectric plant construction, equipment and engineering assistance must be obtained abroad. The decision over what kind of foreign assistance will be sought for which projects is yet to be made. In deciding, Beijing faces a choice between self-reliance and conservation of foreign exchange on the one hand and on the other, speedier construction, reduced input of raw materials, better project design, and the opportunity to see Chinese engineers and geologists trained in modern technology and construction techniques. The areas in which the Chinese will particularly need help are:

- High-head projects where Chinese geological and engineering capabilities appear particularly weak.
- Dams and generating equipment of advanced design that will improve economic efficiency by requiring smaller inputs of raw materials and lower cost per unit of output than projects employing old technologies.
- Heavy construction equipment and management techniques to reduce construction times.

Considering their lack of state-of-the-art engineering skills, the Chinese may have problems with hydro projects that have very high heads. Apparently the highest power dam in China is Liujiaxia, with a height of 147 meters. Among the dams proposed for construction are some with heights of 230 to 270 meters. Because the water pressures are so much greater at these high dams, advanced engineering techniques are required for the design of the dams and hydraulic equipment. China's lack of experience with power dams higher than 150 meters could be a serious liability. Even in the United States, which has many more well-trained engineers than China, there was a recent instance of scroll cases for turbines on a very high-head project failing during preinstallation tests. Redesigning the scroll cases and building new ones cost millions of dollars and kept the plant out of service for more than a year.

It is generally believed that Chinese hydraulic structures were constructed with methods inadequate for high-head development. The Chinese need better design technology and greater mechanization of construction if they are to erect high-head structures in the 200-meter range using turbines discharging water at a high rate. The Chinese might be able to improve designs on their own but this would stretch out the design phase. Moreover, China would have to import the sophisticated hardware needed for modern dam construction.

[7] Also referred to as Lontai in some reports.

In the areas of dam construction and turbine and generator production, Chinese designs and technology are decades behind those in the West. With Japanese or Western engineering, China could build dams using less cement. Modern Western turbines and generators are more compact and use less steel than Chinese models of the same power rating. French, German, Norwegian, Japanese, Swedish, Swiss, or US firms can design and build hydraulic turbines that deliver 10 to 12 percent more power than Chinese units of the same frame size and they would require up to 40 percent less steel to build.

According to Minister of Power Industry Liu Lanbo, China's hydroelectric plant construction capabilities are weakest in geological and hydrological surveying, project design and planning, and construction management. The lack of modern technology and a shortage of experienced personnel needed to conduct geological surveys is adding years to hydro construction projects, according to Vice Minister of Power Industry Li Rui.

There are many indications that China will turn to foreign countries for assistance with hydropower projects. For example, Beijing has announced that a high priority has been assigned to imports that will expand the electric power and other energy industries. In addition the Chinese have been negotiating with many Japanese, US, and European firms for their participation in planned hydro projects. These firms may have submitted cost estimates, feasibility studies, and engineering assessments for a number of projects.

One of China's major goals in seeking foreign assistance with hydro projects is to strengthen its own hydroplant construction industry. The Chinese, therefore, will want to obtain the most advanced technology and training for their engineers. Chinese officials also have said they will look for technology that they can easily assimilate and will seek licenses to manufacture equipment when they can do so economically, rather than import it.

Allocation of Foreign Reserves. One stumbling block for China in negotiating foreign contracts will be financing. Ministries have been directed to submit plans for earning foreign exchange when they apply for permits to import technology or equipment. Because the Ministry of Power Industry does not have its own source of foreign exchange, it probably must look to other ministries for support in foreign exchange requests. For example, the Ministry of Power Industry and the Ministry of Metallurgy are working together on plans to build hydropower stations and aluminum smelting plants. The above-mentioned Jinping and Longtan projects also may be built jointly with the Ministry of Metallurgy.

The Ministry of Metallurgy is not a very large earner of foreign exchange and will have difficulty providing hard currency for the power plants and the metallurgical facilities that will consume the power. The State Planning Commission, therefore, may not be easily persuaded that the projects can be paid for.[8] Nevertheless, there are some indications that the Chinese hope the new metallurgical facilities will allow them to swing from a large net metals importer to a metals exporter. For example, foreign exchange for the Ertan project is supposed to be derived from sale of steel, titanium, and vanadium produced at a nearby steel plant.

China also has been looking abroad for financing for hydroelectric projects and seems to be exploring the possibility of obtaining aid from countries that would supply hydroelectric technology or equipment. For example, China formally asked Japan for a loan in September 1979 to finance eight development projects. Three hydroelectric projects—Longtan, Shuikou, and Wuqiangxi—with an estimated cost of $3 billion were part of the package, though the former two have since been dropped.

500-kV Transmission System in the Works. To make effective use of large new power plants, China will have to step up the capacity of its transmission system. Many of China's transmission lines are now routinely overloaded which undermines the stability of the grids.

Both economic and technological factors are at the root of this problem. Investment in transmission facilities has been inadequate. Like China's hydroelectric de-

[8] Other agencies that must review a request to build a large hydropower plant include the State Economic Commission, Import-Export Control Board, and the State Administration for Foreign Exchange Control.

sign and construction technology, its high-voltage transmission technology is at least 10 years behind that in industrialized nations. China reportedly still has transmission system problems that the United States eliminated when the electric power industry was in its infancy.

The standard long-distance transmission voltage in China is 220 kV. The country has only two 330-kV lines, spanning about 1,000 km in Shaanxi. In comparison, the Soviet Union had 23,800 km of 400- to 500-kV lines at yearend 1978.

China is now installing three 500-kV transmission lines. One will carry power from mine-mouth thermal plants in Anhui to Shanghai, one from Yuanhao Mountain in Liaoning to Dongbei; and one from Pingdingshan in Henan to Wuhan. In addition, China plans to use 500-kV lines at the Gezhouba project and to develop 500-kV intra- and interprovincial grids. Grids utilizing 500-kV lines are likely to appear first in eastern China around Shanghai and then in the Beijing-Tianjin area. As new large hydroelectric plants come on line they will probably transmit power over 500-kV lines.

Five-hundred-kV lines can economically send five to six times the power, about 2.5 times the distance than can 220-kV lines. In addition, by increasing voltages to 500 kV from 220 kV transmission losses are reduced 80 percent, all other factors being kept the same.

Initially China will probably import nearly all of its 500-kV equipment. Recent US visitors to the Xian Switchgear Plant reported that Chinese 500-kV circuit breakers were only in the developmental stage. In recent months Beijing has been negotiating the purchase of 500-kV switchgear, transformers, and substations with Japanese and Western firms. In July equipment was ordered—for a line from Pingdingshan to Wuhan that is scheduled to go into operation in late 1980. Another Chinese order for 500-kV equipment placed with ASEA (Sweden) cost $20 million, according to press reports. Nevertheless, the Chinese want to manufacture their own 500-kV hardware.

At this point, it is difficult to assess how soon China can start producing 500-kV equipment. If Beijing had production licenses in hand, it would probably take a few years to tool up, train technicians, and arrange for supplies of raw materials.

The installation of 500-kV lines also is not likely to proceed rapidly. The lack of trained manpower, technology, materials, and equipment will hamper China's efforts to build a 500-kV system. The Chinese have little experience with high-voltage lines and, regardless of how much information and technology they may import, they are likely to make many mistakes. In addition, materials such as steel for towers and aluminum for conductors are in short supply and construction equipment and techniques are primitive.

Cost may be another factor impeding the installation of 500-kV lines during the next few years, especially when nearly all the equipment will have to be imported. In the United States, such lines now run about $600,000 per km to install. At these prices the costs of constructing 500-kV lines to deliver all of Gezhouba's output to Wuhan would be at least $490 million.

Nevertheless, by the mid-1980s China will probably be manufacturing 500-kV equipment and using it to deliver power from some of the large power plants that will be completed around that time. Also, by the mid-1980s China could have laid the foundations for some regional 500-kV grids.

Outlook

Chinese leaders are well aware of the need for increasing inputs of electrical power to move the economy forward and they recognize the value of tapping China's vast hydroelectric resources.

Before they can move forward, however, the Chinese must overcome two obstacles: project priorities must be established—most likely in coordination with other components of development plans—and funding, particularly in hard currencies, has to be arranged. Fortunately, both issues can be dealt with to some extent on a piecemeal basis. It seems unlikely that the Chinese will wait until 1982 to make or announce all of their decisions. To delay starting survey work on hydroelectric projects until 1982 would push completion dates toward 1990, which in turn would hamper economic development in west, south, and southeast China where coal supplies will be a problem.

It is highly doubtful that China by itself can develop many of the most promising sites for hydroelectric plants within a time frame compatible with desired rates of economic growth. Foreigners will most likely play a critical role in China's hydro development program. In any event, the long leadtimes required and Beijing's lengthy deliberations about power system development plans will be reflected five to 10 years down the road in a power supply that may slow economic growth in the late 1980s and probably will institutionalize blackouts and brownouts as everyday features of Chinese life.

Appendix A

Chinese Hydroelectric Plants

Table A-1

China: Large Hydroelectric Plants Under Construction

Project and Location	Planned Capacity (MW), Units, and Annual Output (kWh)	Planned Construction Sequence [1]	Notes
Gezhouba Hubei on the Chang Jiang	2,700 MW 21 units 13.8 billion kWh	CS: 1970	Dam will be 70 meters high, and 2,560 meters long. Reservoir capacity will be 1.5 billion cubic meters. This is the first dam on the Chang Jiang. The project will have two power houses. The first power house will have a capacity of 965 MW and was reportedly two-thirds complete in September 1979. Technical snags, including the unexpected problem of silting, caused suspension of work from November 1972 to October 1974. The project is closely related to future development of the Sanxia (Three Gorges) and the Chang Jiang water diversion schemes.
Longyangxia Qinghai on the Huang He	1,600 MW 6 billion kWh	CS: 1978	Concrete gravity arch dam will be 172 meters high. Reservoir capacity will be 25 billion cubic meters. Longyang reservoir will regulate flow of water to four existing power stations enabling them to produce another 500 million kWh per year. First generation had been scheduled for 1983, but this date may be pushed back by reported construction delays.
Baishan Jilin on the Songhua Jiang	900 MW 3 × 300 MW	CS: 1975	The concrete gravity arch dam is 150 meters high and 670 meters long.
Ankang Shaanxi on the Han Shui	800 MW 4 units	CS: 1978 EFG: 1982	
Wujiangdu Guizhou on the Wu Jiang	630 MW 3 × 210 MW 3.34 billion kWh	CS: 1970 EFG: 1980	Arched concrete gravity dam is 165 meters high. This is a pilot project in the utilization of water resources in limestone areas, known for their complex geology.
Lubuge Yunnan on the Huangni He	600 MW 4 × 150 MW	EFG: 1985	Tunnel providing a head of 350 meters. Rock-filled dam will be 98 meters high. Resevoir capacity will be 100 million cubic meters. A road has been built to the construction site and a power line brought in.
Dahua Yunnan	500 MW	EFG: 1982	A low head project located near Kunming.

Table A-1

China: Large Hydroelectric Plants Under Construction (continued)

Project and Location	Planned Capacity (MW), Units, and Annual Output (kWh)	Planned Construction Sequence [1]	Notes
Wanan Jiangxi	500 MW	CS: 1978 EFG: 1985	
Luan He Hebei on the Luan He	450 MW 520 million kWh		Dam is 107.5 meters high and 1,040 meters long. Reservoir capacity will be 2.9 billion cubic meters. A multipurpose project, it will supply water to nearby areas and supply power to the North China grid.
Dahua Guangxi on the Hong Shui	First phase: 400 MW 4 units 2.1 billion kWh	CS: 1975 EFG: 1980	Dam is 79 meters high, 967 meters long. This multipurpose project will create a channel for 200-ton ships and provide irrigation.
Tungjiang Hunan	250 to 300 MW	CS: 1958 but was suspended until 1978.	Dam will be 157 meters high.
Shizuishan Ningxia-Nei Monggol border on the Huang He	200 MW		
Taipingshao Liaoning	160 MW	EFG: 1980	
Chingpo Heilongjiang	108 MW 3 × 36 MW		

[1] CS—Construction started. EFG—Expected date of first generation.

Table A-2

China: Hydroelectric Plants of 100 MW or Larger

Plant Name and Location	Capacity (MW), Units, and Annual Average Output (kWh)	Construction Sequence [1]	Notes
Liujiaxia Gansu on the Huang He	1,225 MW 4 × 225 MW plus 1 × 300 MW 5.7 billion kWh	S&P: 1952-1958 CS: 1958 FG: 1969 CC: 1974	Dam is China's largest: 147 meters high and 840 meters long. Project also provides irrigation, flood control, ice flow control, and area for fish breeding.
Danjiangkou Hubei on the Han Shui	900 MW 6 × 150 MW 4.5 billion kWh	CS: 1958 FG: 1968 CC: 1973	Dam is 110 meters high, 2,549 meters long. Project also provides irrigation, flood control, drinking water, and improved navigation.
Gongzui Sichuan on the Dadu He	750 MW 7 units	CS: 1966 FG: 1971 CC: 1979	Dam is 85 meters high, 447 meters long. Project improved navigation, irrigation, flood control, and fish breeding on the Dadu He. Preparations are being made for second stage of the project. Reportedly dam height will be increased to 150 meters, raising capacity to 2,000 MW.
Supong (Dong Sui) Liaoning on the Yalu Jiang	700 MW 7 × 100 MW	CC: before 1949	Dam is 106 meters high, 900 meters long. Reservoir capacity is 6 billion cubic meters. Output is shared with North Korea.
Xinanjiang Zhejiang on the Fuzhun Jiang	652.5 MW 9 × 72.5 MW 2 billion kWh	CS: 1957 FG: 1960 CC: 1977	Dam is 105 meters high, 462 meters long. Reservoir capacity is 17.8 billion cubic meters. Reservoir produced 2.5 million kg of fish annually in the early 1970s and provides flood control, irrigation, and navigation. Plant seems to have been designed for peak load generation.
Dafengman Jilin on the Songhua Jiang	567 MW 8 units 2 billion kWh	Built prior to 1949. Dam was damaged during the war and the Soviets removed some generating equipment. Reconstruction started in 1950. S&P: 1950-53 CS: 1953 FG: 1956 CC: 1959	Dam is about 100 meters high, 1,030 meters long. Supplies power to Anshan, Fushun, and other nearby industrial centers.
Zheji Hunan on the Si Shui	435 MW 6 × 72.5 MW 2.35 billion kWh	CS: 1958 FG: 1962	Hollow concrete dam is 100 meters high, 900 meters long. Reservoir capacity is 1 billion cubic meters. Zheji dam protects hundreds of thousands of hectares of farmland from floods and has improved navigation along a 300-km stretch of the Si Shui. It is heavily used for irrigation.

Table A-2

China: Hydroelectric Plants of 100 MW or Larger (continued)

Plant Name and Location	Capacity (MW), Units, and Annual Average Output (kWh)	Construction Sequence [1]	Notes
Jililung Zhejiang on the Fuzhun Jiang	420 MW 6 × 50 MW plus 2 × 60 MW	CS: 1958	Dam is 48 meters high, 290 meters long. This is a low-head hydroelectric station.
Xingwenping Sichuan on the Min Jiang	400 MW	CS: 1963	
Huladao Unbong Jilin on the Yalu Jiang	400 MW		
Fengtan Hunan on the Yuanshui	400 MW 4 × 100 MW 2.08 billion kWh	CS: 1970 FG: 1978 CC: 1979	
Yanguo Gansu on the Huang He	352 MW	CS: 1958 FG: 1961 CC: 1974	
Yili Cascade Yunnan on the Yili He	322 MW	CS: 1956 FG: 1958	A four power station cascade.
Bikou Gansu on the Bailong Jiang	300 MW 3 × 100 MW	CC: 1977	
Huan-jen Liaoning on the Hun He	290 MW	CS: 1958 FG: 1968	
Xinfenghe Guangdong on the Xinfeng He	290 MW 4 × 72.5 MW 1.2 billion kWh	CS: 1958 FG: 1960 CC: 1962	The concrete dam is 128 meters high, 450 meters long. Reservoir capacity is 13 billion cubic meters.
Qingtongxia Ningxia on the Huang He	272 MW 8 units 1.3 billion kWh	CS: 1958 FG: 1967 CC: 1978	
Gutian Cascade Fujian on the Gutian Xi	262 MW in four power stations	CS: 1950 FG: 1958 CC: 1971	Supplies power to the North Fujian grid.

Sanmen Henan on the Huang He	250 MW 5 × 50 MW	CS: 1958 FS: 1973 CC: 1979	Project was to have had a capacity of 1,100 MW but silting problems forced the Chinese to redesign Sanmen with fewer and smaller units. Design capacity is now 250 MW. Dam is 110 meters high, 960 meters long. The reservoir reportedly flooded about 130,000 hectares of farmland, 150 km of railroad tracks, and 2,000 populated areas requiring relocation of 600,000 people.
Maotiao Cascade Guizhou on the Maotiao He	240 MW in five power stations	CS: 1958	The fifth power station was completed in December 1979. Planned capacity was to be 300 MW in six stations.
Xijin Guangxi on the Xi Jiang	228.8 MW 4 × 57.2	CS: 1958	A low-head project.
Fengshapa Guandong on the Dong Jiang	225 MW 3 × 75 MW	CS: 1970 FG: 1973	
Bapan Gansu on the Huang He	180 MW 5 × 36 MW	CS: 1969 FG: 1975 CC: 1979	
Zelin Jiangxi on the Xiu Shui	180 MW 4 × 45 MW	CS: 1958	Reservoir capacity is 7.2 billion cubic meters. Original planned capacity was 264 MW with annual output of 690 million kWh.
Xier Cascade Yunnan on the Xier He	175 MW in two power stations	CS: 1958, but apparently suspended until 1966. FG: 1971	When completed the project will have four hydroelectric stations along a 20-km section of the river with a total capacity of 255 MW. The third station is under construction.
Hunanzhen Zhejiang on the Wuxi He	170 MW 4 × 42.5 MW	CC: 1979	Dam is 129 meters high and 440 meters long with reservoir capacity of 2 billion cubic meters.
Huanglungtan Hubei on the Du He	150 MW 2 × 75 MW	CS: 1969 CC: 1974	
Chencun Anhui on the Shu Xi	150 MW 3 × 50 MW	CS: 1958 CC: 1975	
Shiquan Shaanxi on the Han Shui	135 MW 3 × 45 MW	FG: 1973 CC: 1975	
Shuangpai Hunan on the Xiang Jiang	130 MW		
Tianqiao Shanxi-Shaanxi border on the Huang He	120 MW 4 × 30 MW		

Table A-2

China: Hydroelectric Plants of 100 MW or Larger (continued)

Plant Name and Location	Capacity (MW), Units, and Annual Average Output (kWh)	Construction Sequence [1]	Notes
Pao-te Shanxi	120 MW		
Ansha Fujian on the Jiulong Xi	115 MW 3 units	CS: 1970 FG: 1975	Dam is 92 meters high.
Longchi Cascade Sichuan on the Longchi River	108 MW in four power stations	CS: 1955 FG: 1957	
Mashek Guangxi on the Yung River	100 MW 3 units	CS: 1970 CC: 1977	

[1] S&P: Surveying and planning.
CS: Construction started.
FG: First generation.
CC: Construction completed.

Table A-3

China: Proposed Major Hydroelectric Development Projects

Project	Location	Capacity (and Units)	Notes
In the Chang Jiang Basin			
Baihetan	Yunnan-Sichuan border near Ningnan on the Jinsha Jiang	10,000 MW	Concrete dam will be 270 meters high. Geological surveys and designing are under way.
Ertan	Sichuan on the Yalong Jiang near Dukou	3,000 MW	Annual output will average 16 billion kWh. Dam will be about 240 meters high, 900 meters long. Construction time expected to be five years. Cost is estimated at $1.5 billion. Project will provide power to Panzhihua steel mill and titanium and vanadium production facilities in the area.
Jinping	Sichuan on the Yalong Jiang about 175 km north of Dukou	Stage 1: 1,500 MW Stage 2: 1,500 to 3,000 MW Stage 1 upgrading: 1,500 MW	Annual output will average 11.4 billion kWh for the first stage; 8.9 billion to 18.2 billion kWh for the second stage. Upgrading the first stage will generate another 9.1 billion kWh. The first stage will consist of a low dam and two 16 km power tunnels across a loop in the river to create a 300-meter head. The second stage, located a few km upstream from the low dam, will be a high dam with a head of 165 or 265 meters depending on the design chosen. Two more power tunnels may be added to the first stage after the second stage is completed. Power will be used at a nearby steel plant.
Sanxia	Hubei on the Chang Jiang near Yichang	25,000 MW (25 × 1,000 MW) First phase, 10,000 MW	Annual output will average 120 billion kWh. Concrete gravity dam will be 230 meters high. Construction time will be eight to 10 years to first generation; 20 years to completion. Cost reportedly estimated at $7.8-12.1 billion. Much geological survey work has been done, but a dam site has not yet been selected.
Xiangjiaba	Sichuan-Yunnan border on the Jinsha Jiang near Pingshan	4,000 to 6,000 MW	Earth-rock dam will be 130 meters high. Geological surveys and design work are under way.
On the Huang He			
Daliushu	Ningxia near Zhongwei Xian	1,500 MW	Geological surveys had not yet begun as of December 1978.
Longmen	Shaanxi-Shanxi border	1,500 MW (5 × 300 MW)	Annual output will average 6 billion kWh. Dam will be 200 meters high. Reservoir capacity of 12.5 billion cubic meters will eventually be reduced by sediment to 3.8 billion cubic meters. Geological surveys were under way in December 1978.

Table A-3

China: Proposed Major Hydroelectric Development Projects (continued)

Project	Location	Capacity (and Units)	Notes
Xiaolongdi	Henan	1,600 MW (4 × 400 MW)	Annual output will average 6.5 billion kWh. Dam will be 151 meters high. Reservoir capacity of 12.7 billion cubic meters will eventually be reduced to 3.8 billion cubic meters by sediment.
Projects on Other Rivers			
Longtan	Guangxi on the Hong Shui, 16 km upstream from Tian'e	3,000 MW	Annual output will average 13.4 billion kWh. Concrete arched gravity dam will be 200 meters high. Reservoir will hold 16.5 billion cubic meters. Two years will be needed for geological and hydrological surveys and designing before construction can begin. Construction will take about six years. Cost is estimated at between $970 million and $1.55 billion. Longtan is being planned in conjunction with an aluminum plant.
Tienshengqiao	Guizhou-Guangxi border on the Nanpan Jiang near Xingyi	Stage 1: 800 MW Stage 2: 1,600 MW Stage 1 upgrading: 400 MW	Annual output of first stage will average 4.7 billion kWh; the second stage, 5.3 billion kWh. The first stage will have a low diversion dam and two 11 km pressure tunnels to create a head of 200 meters. For the second stage a high dam will be built upstream from stage 1, creating a reservoir capable of holding 9 billion cubic meters of water. After the second stage is completed, stage 1 will be upgraded to 1,200 MW, generating 8.3 billion kWh. Work on stage one has reportedly begun.
Shuikou	Fujian on the Min Jiang	1,400 MW (7 × 200 MW)	Annual output will average 5 billion kWh. Dam will be 95 meters high. Construction will reportedly take six years. Cost is estimated at $840 million of which $630 million will be in foreign exchange. Shuikou will supply power to factories that may be built in Fujian by foreigners, particularly overseas Chinese.
Wuqiangxi	Hunan	1,500 MW	Annual output will average 7 to 8 billion kWh. The dam will be 100 meters high. Reservoir will have capacity of 5.7 billion cubic meters. At least six years will be needed for construction; cost is estimated at $810 million, of which foreign exchange is $690 million. This project is supposed to supply power to Wuhan.
Datengxia	Guangxi on the Hong Shui near Guiping	1,200 MW	Annual output will average 5.5 billion kWh before upstream reservoirs are built.

Appendix B

China: Natural Gas Production

Table B-1

China: Natural Gas Production

	Billion Cubic Meters			Percent
	National	Sichuan	Other	Sichuan Share
1957	0.67	0.66	0.01	98.5
1965	1.11	0.85	0.26	76.6
1970	3.84			
1971	4.80			
1972	5.54	2.55	2.99	46.0
1973	6.39			
1974	7.35	2.72	4.63	37.0
1975	9.19	3.40	5.79	37.0
1976	10.20	5.10	5.10	50.0
1977	12.48			
1978	13.73	7.53	6.20	55.0
1979	14.51			

Table B-2

Source Notes for Appendix B

	National	Sichuan
1979	State Statistical Bureau Communique. (FBIS, 30 Apr 80, L-2)	
1978	Derived from 1979 output and the claim that 1979 output increased 5.7 percent over 1978. (FBIS, 30 Apr 80, L-2)	Residual derived by subtracting reported natural gas output at Daqing and Panshan fields and an estimate for other oilfields from national output. The 55-percent Sichuan share is compatible with Chinese claims that Sichuan was still producing most of China's natural gas. (FBIS, 27 Sep 78, L-11)
1977	Derived from output in 1978 and the reported increase of 10 percent over 1977. (FBIS, 5 Jan 79, E-28)	
1976	Derived from outupt in 1977 and the reported increase of 22.3 percent over 1976. (FBIS, 27 Dec 77, E-9)	Derived from 1965 output and the claim that 1976 Sichuan output was 6 times 1965. (FBIS, 2 Jun 77, J-1)
1975	Derived from output in 1976 and the reported increase of 11 percent over 1975. (FBIS, 6 Jan 77, E-19)	Derived from 1965 output and the claim that 1975 output was 4 times 1965. (*Chengdu*, 4 May 76, FBIS, 5 May 76, J-2)
1974	Assume a 25-percent increase 1975 over 1974. This rate is justified by 1975 having been a year of rapid recovery from a previous very poor economic year for China, and is in line with the recovery rate achieved by the economy as a whole.	Derived from 1965 output and the claim that 1974 Sichuan output was 3.2 times 1965. (FBIS, 16 Jan 76, J-1)
1973	Derived from 1974 output and the claim that 1974 increased nearly 15 percent over 1973. (FBIS, 3 Jan 75, E-10).	
1972	There is no official claim that allows direct calculation of 1972 national gas output. It was assumed that output in 1973 increased by 15.25 percent the midpoint between the increase of 15.5 percent in 1972 and 15.0 percent in 1974. Output in 1972 then was calculated as 6.40 ÷ 1.1525 or 5.56.	Derived from 1965 output and the claim that 1972 Sichuan output was 3 times 1965. (*Xinhua Chengdu*, 16 Sep 73)
1971	Derived from 1972 output and the claim that during the first 8 months of 1972, output increases 15.5 percent over the same period of 1971 (FBIS, 28 Sep 72, B-1).	
1970	Derived from 1971 output and the claim that 1971 increased 25 percent over 1970 (*Beijing Review*, 21 Jan 72, p. 3).	
1965	Derived from 1976 output and the claim that 1976 was 9.2 times 1965. (FBIS, 16 Aug 77, E-1)	Derived from 1978 output and the claim that between 1965 and 1978, Sichuan gas output increased nearly 8 times. We have calculated using 7.9 times. [See Sichuan 1978 note (*Dagong Bao*, 16 Aug 79, p. 12)]
1957	Derived from Sichuan output and Sichuan's assumed 99 percent share of total output in 1957.	Sichuan output was 0.66 billion cubic meters (*Dili Zhishi*, No. 10, 1958, p. 458)


China: Hydroelectric Power Plants
Greater than 1000 MW
500–999 MW
Less than 499 MW
Operational
Under construction
Proposed
International boundary
International boundary, in dispute
Other line of separation
Internal administrative boundary
National capital
Scale 1:10,000,000
Kilometers
Nautical Miles
Statute Miles
Lambert Conformal Conic Projection, Standard Parallels 23° and 45°
Names and boundary representation are not necessarily authoritative
Unclassified
Mongolia
Nei Monggol
Xinjiang
Xizang
Qinghai
Gansu
Sichuan
Yunnan
Guizhou
Guangxi
Guangdong
Hunan
Hubei
Jiangxi
Fujian
Zhejiang
Anhui
Jiangsu
Shandong
Henan
Shaanxi
Shanxi
Hebei
Ningxia
Beijing
Liaoning
Jilin
Heilongjiang
North Korea
South Korea
Japan
Sea of Japan
Yellow Sea
Bo Hai
East China Sea
South China Sea
Philippine Sea
Gulf of Tonkin
Bay of Bengal
Taiwan
Hong Kong (U.K.)
Macao (Port.)
Hainan Dao
Philippines
Vietnam
Laos
Thailand
Burma
India
Nepal
Bhutan
Bangladesh
Pakistan
Afgh.
Shanghai
Luzon Strait
Formosa Strait
Tropic of Cancer
Gezhouba
Sanmen
Liujiaxia
Longyang Xia
Xinfengjiang
Fengtan
Gongzui
Dahua
Longtan
Supong
Chingpo
Baishan